THE OHIO STATE UNIVERSITY

A Petrographic Examination of a Suite of Regionally Metamorphosed Rocks from the Southbridge Formation, Southbridge Quadrangle, Connecticut-Massachusetts

by

Fred G. Galliers

A THESIS SUBMITTED
IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF SCIENCE

Senior Thesis Advisor

Dr. George E. Moore, Jr.

Columbus, Ohio

February, 1974

TABLE OF CONTENTS

INTRODUCTION

The regionally metamorphosed rocks in this study are from the Southbridge Formation, Windham County, Connecticut and Worcester County, Massachusetts. They were collected by Dr. George E. Moore,Jr. of the Ohio State University in 1972 and were thin-sectioned by the United States Geological Survey.

The Southbridge Formation was adopted in 1972 by Maurice H. Pease,Jr., who designated the type section as line A-A' (map,p.ii,app.). Pease assigned a lower and an upper member to the formation, but only the upper member is exposed in the type section. The lower member is described as dark gray biotite gneiss and schist alternating with a light gray quartzo-feldspathic gneiss. The upper member is mostly medium to dark gray schist and gneiss with interlayers of biotite-muscovite-garnet-sillimanite gneiss, biotite-sulfide-graphite schist, and layered amphibolite.

The general attitude of the formations in the area is a northeast trending strike and dip to the northwest with local overturning. Overall, the Southbridge Formation shows top-facing to the northwest, which can be inferred from local cross-bedding and from gradations in grain size. The pre-Acadian age of Ordovician (?) to Silurian (?) has been assigned to the Southbridge Formation and the overlying Bigelow Brook and Hebron Formations.

Major faults in the area have a northeastern trend, whereas cross-cutting faults trend in a general northwestern direction. In the Eastford quadrangle, Connecticut, Pease has mapped one of the master faults, the Black Pond fault, as the boundary between the Southbridge Formation on the southeast and the Bigelow Brook Formation on the northwest. If the trace of this fault as so mapped is projected into the Southbridge quadrangle, it follows through the swampland immediately west of the location of samples 29 A and 29 C to the eastern edge of the town of Southbridge (map,p.ii,app.). If this projection is indeed accurate, it is likely that there is a cross fault through the Quinebaug River valley creating the apparent westward displacement of the contact between the Bigelow Brook and the Southbridge Formations northeast of Southbridge.

METAMORPHISM

A belt of high-grade metamorphic facies of the Barrovian type series extenting from eastern Connecticut north through Massachusetts, New Hampshire, and Maine was described by Lundgren (1966). This belt, corresponding to the almandine-amphibolite facies, encompasses the Southbridge and the Bigelow Brook Formations. Lundgren realized that an important element of the late Paleozoic metamorphism throughout this belt was the reaction of muscovite, sodic plagioclase, and quartz at increasing grades to produce sillimanite, orthoclase, and higher calcic plagioclase.

This reaction allows for the recognition of an isograd in pelitic schists between the kyanite-almandine-muscovite subfacies and the sillimanite-almandine-orthoclase subfacies. The later is the higher metamorphic grade. In the Eastford quadrangle, Pease recognized this isograd to be coincident with the Keach Pond fault, approximately 4,000 feet west of and nearly parallel to the previously mentioned Black Pond fault. To the northwest of this isograd is the higher grade sillimanite-almandine-orthoclase subfacies, and to the southeast is the kyanite-almandine-muscovite subfacies, to which the Southbridge Formation belongs.

The Barrovian type facies series is characterized by Winkler (1967) as that produced under high pressure conditions. The greenschist facies is indicative of accompanying

low temperature, whereas the almandine-amphibolite facies is indicative of high pressure and high temperature .

Minerals common to the almandine-amphibolite facies are: staurolite, garnet, diopside, cummingtonite, anthophyllite, and gedrite. Kyanite is often present, but it is found elsewhere, and in the higher grades it is replaced by sillimanite. Epidote and zoisite are stable through part of this facies as well as in the greenschists, but here they are associated with oligoclase or andesine as opposed to albite.

PARENT ROCKS

Turner and Verhoogen (1960) broke down the almandine-amphibolite facies into the following subfacies:

B 2.1 - staurolite-almandine
B 2.2 - kyanite-almandine-muscovite
B 2.3 - sillimanite-almandine-orthoclase

Since the Southbridge Formation is in a lower grade subfacies than B 2.3, the paragenetic relationships characteristic of this subfacies will be disregarded.

In the specimens studied, no staurolite or kyanite was noted. This makes the precise identification of the exact subfacies to which the Southbridge Formation belongs impossible because the only appreciable difference between the B 2.1 and B 2.2 subfacies is the replacement of staurolite by kyanite in metamorphosed pelites. The other characteristic assemblages are virtually the same in both of the subfacies.

The following is a summary of the typical mineral assemblages formed from the metamorphism of various types of parent materials (after Winkler, 1967, p.108-109):

pelitic rocks- kyanite, staurolite, muscovite, (paragonite, biotite) (plagioclase, quartz)
- staurolite, almandine, muscovite, (paragonite, biotite) (plagioclase, quartz)
- almandine, muscovite, biotite, (plagioclase)
- epidote, quartz

marls- plagioclase, epidote, hornblende, (almandine) (muscovite) (quartz)
- plagioclase, epidote, hornblende, diopside, (muscovite) (quartz)

siliceous carbonates- calcite, diopside, grossularite, (quartz)
- calcite, diopside, tremolite

basic rocks- hornblende, plagioclase, epidote, (almandine) (biotite) (quartz)
- hornblende, plagioclase, epidote, (diopside)

ultrabasic rocks- hornblende, almandine, cummingtonite, or anthophyllite, or gedrite

A comparison of the assemblages listed above and the assemblages found in the specimens from the Southbridge Formation (p. iv,app.) shows that few of the samples have a simple parentage.

Pease (1972) proposed a waterlain pyroclastic origin for most of the Southbridge formation. This explanation not only accounts for the conspicuous sedimentary layering and cross-bedding, but also explains the highly variable mineral content of the rocks. The calc-silicate mineral content is attributed to calcareous cement and limy muds interlaced with pyroclastic material from rhyolitic to basaltic composition. The occasional high content of pyrite and graphite in these gneisses could be the result of deposition in an anaerobic environment.

The occurance of medium to coarse grained, light gray lensatic pods of gneiss is common in the upper Southbridge. These range widely in size from a few inches to a number of feet. A good example is specimen 7 A (p. vi, app.), which has a high microcline, quartz, and plagioclase content. Biotite, muscovite, and garnet are present in smaller amounts.

The most interesting aspects though are the large grain size (up to 6 mm) and the cataclastic texture. Evidently,

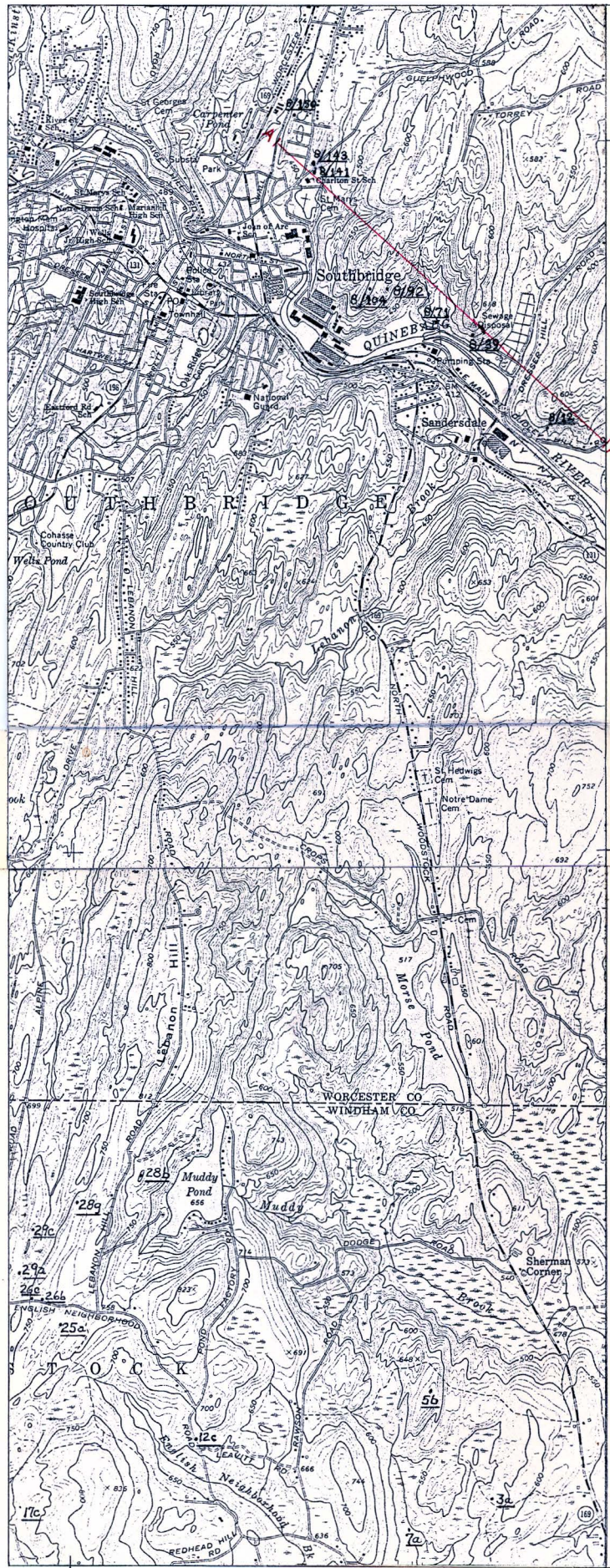
this specimen was recrystallized from a somewhat acidic pyroclastic sediment to a coarse grained rock by anatexis at high pressure and temperature. It was subsequently mechanically deformed by shearing movement, reducing the grain size and producing the granulated matrix. During the deformation, the heat was persistent enough to cause the growth mosaic structures between the porphyroclasts and the matrix.

APPENDIX

INDEX MAP OF SPECIMENS STUDIED

Note:

The following map is a photostatic reproduction of a portion of the Southbridge Quadrangle, Massachusetts-Connecticut. Although specimens 17C and 28G are indicated, they were not available for investigation.



SOUTHBRIDGE QUADRANGLE
MASSACHUSETTS—CONNECTICUT

SCALE 1:24000

1 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 5 0 1 KILOMETER

MN 14° N

MODAL COMPOSITIONS
and
DESCRIPTIONS OF SPECIMENS 3 A - 8/150

Note:

For simplicity, all of the following specimens should be thought of as gneisses. In some, the foliation and layering in the hand specimen or thin-section is on such a scale as to be unnoticeable; but when they are considered on a larger scale, they are indeed predominately gneissic.

MODAL COMPOSITIONS

	3 A	7 A	25 A	29 A	5 B	26 B	28 B	12 C	26 C	29 C	8/12	8/39	8/71	8/92	8/104	8/141	8/143	8/150
Quartz	43	31	35	32	32	35	20	45	32	22	54	38	47	53	31	42	53	34
Plagioclase	32	16	30	4	28	19	62	22	28	40	22	35	22	24	8	17	13	23
Microcline		41		36	11							1			39			
Biotite	18	6	1	12	21	16	14	19	15		17	7	9	5	2	½	14	13
Muscovite	3	4	tr	3	4	12					tr			tr	3		tr	6
Hornblende			21					3	10	5	5	1	8	3		7	14	tr
Grunerite			7						8							1		1
Actinolite			½	tr				tr	3	1				7			1	1
Diopside				8				8		24		16	12	2				
Garnet	½	1				8	3				½							
Epidote										tr				tr	tr			
Clinozoisite		tr	tr				tr		tr					3		tr		1
Sericite	tr	tr	tr	8	2	7	tr	tr	tr	tr	tr		½	½	5	9	3	9
Chlorite	1½	tr		tr	1			tr	tr	tr				tr	9	12	½	7
Sphene	tr		½	tr				tr		3	tr	1	½	1		½		
Zircon	tr	tr	tr	tr	tr	tr	tr	1	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr
Apatite	tr	tr	tr		tr	tr	tr	tr	tr		tr	tr	tr	tr	tr	tr	tr	1
Rutile	tr		tr	½	tr	½	tr		tr	tr	tr	tr	tr	tr	tr		tr	
Tourmaline											½							
Monazite			tr							tr							tr	
Carbonate	½		tr					tr		4		tr						
Pyrite	tr		2½		tr	½	tr	tr	2	tr	tr	tr	tr	½	tr	7	tr	
Hematite	tr	tr	tr	tr	tr	½		½		tr	tr	tr		tr			tr	tr
Magnetite			tr				tr		tr							tr		tr
Graphite	½	tr	½	tr	tr	½	tr	tr	1		tr		tr	tr		tr	½	2
Iron oxide & clay dust	tr	tr	1	3½	tr	tr	tr	½	tr	tr	tr	tr	tr	tr	2	3	tr	1
% Anorthite in plag.	45	40	64	40	38	40	46	48	62	59	39	40	45	54	36	48	52	47

SAMPLE 3 A-

Hand Specimen

Medium gray with slight greenish cast on fresh surface, weathers to slight brownish gray. Groundmass of fine grained quartz, plagioclase, and biotite with medium grained porphyroblasts of quartz, plagioclase and garnet. Good foliation of biotite with some crenulation and interrupted by quartzo-feldspathic vienlets up to 2 mm thick.

Thin-section

-Composition

Quartz, plagioclase, biotite, muscovite, chlorite, garnet, carbonate, and graphite. Traces of sericite, sphene, zircon, apatite, rutile, pyrite, hematite, and iron oxide stain and clays.

-Summary description

Crystalloblastic texture with xenoblastic porphyroblasts of quartz, plagioclase, and garnet. Garnet blasts are poikiloblastic with inclusions of oval-shaped quartz. Preferred orientation of biotite and chlorite produces foliation which bends around the porphyroblasts. The muscovite grains for the most part are oriented to this foliation, but on occasion they are not which indicates a post deformation age. They are invariably intergrown with plagioclase. Carbonate is sprinkled throughout in intersticies. Quartz with undulose extinction is found in long 1 mm thick trains and in the groundmass. Some plagioclase twins are deformed and areas with slight granulation are frequent which indicates mechanical deformation.

Only a small amount of sericite is present in the plagioclase grains.

SAMPLE 77 A-

Hand Specimen

Light yellow-gray on fresh surface, weathers to buff color. Has general gneissic foliation of biotite which undulates around large (up to 6 mm) porphyroclasts of quartz, microcline, plagioclase and garnet. The matrix is of the same material but much finer grained and granulose.

Thin-section

-Composition:

Quartz, microcline, plagioclase, biotite, muscovite, and garnet. Traces of clinozoisite, sericite, chlorite, zircon, apatite, hematite, and graphite.

-Summary description

Cataclastic texture with porphyroclasts of quartz, microcline, and plagioclase, up to 4 mm in a fine grained matrix of quartz, microcline, plagioclase, biotite, and muscovite. Grains around the clasts show a definite growth mosaic structure due to recrystallization at the time of mechanical deformation.

Garnet grains appear to be porphyroblasts with poikiloblastic texture. They are xenoblastic in form. Muscovite is also porphyroblastic and is often subparallel to the general foliation. Its association with plagioclase is marked throughout.

Quartz, microcline and plagioclase porphyroclasts are fractured. Displacement and stress-bending of twins is common. Quartz shows undulose extinction.

Alteration in the specimen is slight.

SAMPLE 25 A-

Hand Specimen

Dense, fine grained, dark olive on the fresh surface, weathering to deep rusty brown. Obscured lineation of amphiboles and crude compositional layering noticeable. Pyrite, along with quartz and plagioclase, are also identifiable in hand specimen.

Thin-section:

-Composition

Quartz, plagioclase, hornblende, grunerite, pyrite, biotite, iron oxide dust and clays, graphite, sphene, and actinolite. Traces of muscovite, clinozoisite, sericite, zircon, apatite, rutile, monazite, carbonate, magnetite, and hematite.

-Summary description

Crystalloblastic texture with an average grain size of 0.4 mm. All major minerals tend to have a dimensional preferred orientation which in the amphiboles (hornblende and grunerite) leads to lineation. Pyrite is sprinkled throughout the specimen at triple points with irregular form. Graphite is found at the grain boundaries of quartz and plagioclase and is sub parallel. Small amounts of biotite, graphite and muscovite are the only platy minerals present to produce foliation. Sphene is found as subhedral grains up to 0.1 mm sprinkled throughout.

SAMPLE 29 A-

Hand Specimen

Light yellow gray on fresh surface, weathering to medium gray. Porphyroclasts of medium grained quartz and microcline in a granulose matrix of fine grain quartz-feldspathic material. Thin, discontinuous dark bands rich in biotite undulate around porphyroclasts.

Thin-section

-Composition:

Quartz, microcline, biotite, sericite, plagioclase, iron oxide dust and clays, muscovite, and rutile. Traces of actinolite, chlorite, sphene, zircon, hematite, and graphite.

-Summary description

Cataclastic texture with porphyroclasts of quartz, microcline and plagioclase up to 2.5 mm in a fine grained granulose matrix of quartz, microcline, biotite, and plagioclase with somewhat larger grains of muscovite associated with plagioclase.

In overall appearance, this sample is similar to 7A except for the lack of garnet porphyroblasts and the invasion of the matrix and porphyroclasts by sericite. A larger amount of iron oxide dust and clay minerals are present.

In this specimen quartz trains are more highly developed which are a linear aggregate of quartz grains with sutured boundaries and undulose extinction.

SAMPLE 5 B-

Hand Specimen

Overall dark gray on fresh surface, weathering to a deep rusty gray brown. Excellent foliation of biotite in a fine grained matrix undulating smoothly around augen shaped porphyroclasts of quartz, microcline, and plagioclase up to 12 mm in length. Muscovite and graphite also noticeable in hand specimen.

Thin-section

-Composition:

Quartz, microcline, biotite, sericite, plagioclase, muscovite, and chlorite. Traces of zircon, apatite, rutile, pyrite, hematite, graphite, and iron oxide dust and clays.

-Summary description

Similar to 7A and 29A. Cataclastic texture with porphyroclasts of quartz, plagioclase and microcline surrounded by well foliated granulose groundmass of quartz, plagioclase, microcline, biotite, and porphyroblastic muscovite. This specimen has a higher biotite content than the previous two, and the porphyroblasts of muscovite have attained a size of 1-2mm. The twins of the feldspars show more dislocation along the cracks than before and the stringers of quartz show more highly sutured boundaries. This coupled with a highly developed network of growth mosaic structures between the groundmass and the porphyroclasts indicates a higher degree of cataclastic deformation than in the previous samples.

Sericite has invaded the plagioclase to a modest degree and less so in the microcline. Much of the thin-section is covered with a fine iron oxide and clay mineral dust.

SAMPLE 26 B-

Hand Specimen

Medium gray on fresh surface, weathering to reddish brown. Fine grained matrix of quartz, feldspar, biotite, and muscovite with a highly irregular foliation of the platy minerals. Large clasts (up to 6 mm) of plagioclase and quartz are common as are porphyroblasts of lavender garnet. Muscovite is readily visible in the hand specimen giving rise to a shimmering foliation. A large ovoid mass of very fine grained texture approximately 7 cm long is noticeable and is quite probably a relict structure.

Thin-Section

-Composition:

Quartz, plagioclase, biotite, muscovite, garnet, sericite, pyrite, hematite, graphite, and rutile. Traces of zircon, apatite, and iron oxide dust and clay minerals.

-Summary description

The overall structure of this sample microscopically is very near that of 5 B. The cataclastic deformation has produced the same structures as before, but here the amount of muscovite is noticeably higher, as is the amount of garnet porphyroblasts. The garnet grains are xenoblastic and highly included. Sericite has appeared in the groundmass and in the porphyroblasts. Graphite, hematite, pyrite, and rutile are all intergrown extensively with the biotite.

SAMPLE 28 B-

Hand Specimen

Light medium gray on fresh surface, weathering to a brown or dark gray. Fine grained with a homogeneous mineralic content of plagioclase, quartz, and biotite with somewhat larger porphyroblasts of lavender garnet. A crude foliation is produced by a subparallel arrangement of biotite.

Thin-section

-Composition:

Plagioclase, quartz, biotite, and garnet. Traces of zircon, apatite, rutile, magnetite, pyrite, graphite, sericite, and iron oxide dust and clay minerals.

-Summary description

Crystalloblastic texture with an average grain size of 0.5 mm. Evenly dispersed porphyroblasts of garnet approximately 1 mm in diameter are xenoblastic with common inclusions of quartz, plagioclase and, on occasion, magnetite. These are in a matrix of quartz, plagioclase, and subparallel biotite grains. The quartz exhibits undulose extinction and the twin lamellae of the plagioclase are bent and dislocated along numerous fractures.

Alteration of this sample is slight with minute amounts of sericite in the plagioclase and a small amount of clay mineral dust.

SAMPLE 12 C-

Hand Specimen

Medium brownish gray on fresh surface, weathering to darker gray. Quartzo-feldspathic layers of variable grain size and dimensions cut a matrix of fine grained, foliated quartz, plagioclase, biotite, and diopside. Compositional layering is noticeable in the hand specimen.

Thin-section

-Composition:

Quartz, plagioclase, biotite, diopside, hornblende, zircon, hematite, iron oxide dust and clays. Traces of actinolite, chlorite, sericite, apatite, carbonate, and graphite.

-Summary description

The texture is in part cataclastic, but layers with crystalloblastic texture are present. Porphyroblasts of diopside up to 1.5 mm are poikiloblastic with inclusions of quartz. These crysts are blocky, xenoblastic, and altered on the edges to hornblende. Quartzo-feldspathic layers and lenses cut a fine grained matrix of quartz, plagioclase, biotite, and hornblende. The biotite shows good development of planar orientation.

There is a noticeable degree of compositional layering in the diopside, which,along with growth structures, stress bent plagioclase twins, and granulation indicates mechanical deformation.

Alteration of the sample is slight with only small amounts of sericite present. Weathering has produced a clay dust over much of the thin-section.

SAMPLE 26 C-

Hand Specimen

Medium gray on fresh surface, weathering to darker gray. Fine grained quartz, feldspar, biotite, and amphiboles with even foliation and small strings of quartzofeldspathic composition. Compositional layering is appearant on a cut surface.

Thin-section

-Composition:

Quartz, plagioclase, biotite, hornblende, grunerite, actinolite, pyrite, and graphite. Traces of clinozoisite, sericite, chlorite, apatite, rutile, magnetite, and iron oxide dust and clay minerals.

-Summary description

Fine grained crystalloblastic texture with an average grain size of 0.4 mm. Quartz, plagioclase, and biotite persist throughout the section, but layers rich in biotite alternate with others rich in amphiboles, which show crude preferred orientation. This pattern is cut by irregular, thin trains of quartz with sutured boundaries.

The existence of three amphiboles--hornblende, grunerite and actinolite in this specimen is somewhat unsure. But the indicies, pleochroism, and the form show three variations. Hornblende is pleochroic in green and brown and has moderately high indicies, whereas, grunerite shows polysynthetic twinning, high indicies and a neutral to pale brown color. Actinolite has a moderate index, colorless to pale green color and occurs in somewhat fibrous masses. Pyrite and graphite are common with the former showing a subparallel arrangement.

This sample has only trace amounts of sericite.

SAMPLE 29 C-

Hand Specimen

Medium gray-green on fresh surface, weathers to a light brownish gray. Fine grained matrix of quartz and plagioclase with porphyroblasts of diopside. The specimen shows compositional layering of diopside and irregular pods and lenses of quartz and feldspar. Porous area are common.

Thin-section

-Composition:

Plagioclase, quartz, diopside, hornblende, carbonate, sphene, and actinolite. Traces of epidote, zircon, rutile, monazite, pyrite, hematite, sericite, and iron oxide dust and clay minerals.

-Summary description

Overall crystalloblastic texture of fine grained (0.5 mm) quartz and plagioclase with porphyroblasts of diopside up to 2 mm. The diopside is blocky in form and altered deeply on the edges to amphibole. Slight granulation in the matrix is present. Sphene and free growing crysts of amphibole show a preferred orientation, which, along with the compositional layering of diopside produces a plane of foliation. Carbonate amounts to 4% of the specimen and is found as formless grains in interstitial voids.

Sericite is present in small amounts in the plagioclase and a small amount of iron oxide dust and clay minerals are scattered about the section.

SAMPLE 8/12-

Hand Specimen

Medium dark gray on fresh suface, weathering to brownish dark gray. The fine grained massive matrix of quartz, feldspar, biotite and amphibole is cut by lenses of quartz up to 3 mm. A faint trace of lineation is noticeable in the direction of the foliation produced by biotite. Porphyroblasts of garnet are present.

Thin-section

-Composition:

Quartz, plagioclase, biotite, hornblende, garnet, and tourmaline. Traces of muscovite, sericite, sphene, zircon, apatite, rutile, pyrite, hematite, graphite, and iron oxide dust and clays.

-Summary description

Overall crystalloblastic texture with distortion of grains in general direction of the foliation produced by biotite. The average grain size is 0.3 mm, but the sample is cut by large ribbons of quartzo-feldspathic composition 1-2 mm thick. These bands are predominately monomineralic in quartz, but near the edges plagioclase grains are distinctly larger than elsewhere. These bands along with layers rich in porphyroblasts of hornblende, produce a well defined gneissosity. The orientation of these grains also causes a crude lineation in the plane of foliation. Porphyroblasts of garnet and occasionally tourmaline are xenoblastic and included.

Very slight stress-bending in the plagioclase and undulose extinction of the quartz grains is present.

Alteration of the plagioclase to sericite is only occasionally found. The bulk of the sample is quite fresh.

SAMPLE 8/39-

Hand Specimen

Overall medium to dark gray on fresh surface, weathering to brown-gray. Fine grained greenish layers rich in quartz, feldspar and calc-silicate thinly interlaced with thin medium grained quartzo-feldspathic lenses. Occasional sphene crysts are noticeable.

Thin-section

-Composition:

Quartz, plagioclase, diopside, biotite, sphene, hornblende, and microcline. Traces of zircon, apatite, rutile, carbonate, pyrite, hematite, and iron oxide dust and clays.

-Summary description

In part porphyroblastic texture with foliation produced by biotite. Porphyroblasts of blocky diopside average 0.5 mm in a finer grained matrix of quartz, plagioclase, and biotite. Lensatic stringers of quartz and plagioclase up to 1 mm thick cut the matrix. Stress bent plagioclase twins, undulose extinction in quartz, intermittent granulation, growth mosaic structure, and sutured quartz boundaries indicate a degree of cataclastic deformation.

The diopside porphyroblasts are somewhat poikiloblastic with inclusions of quartz and plagioclase. Around the edges they are commonly altered to hornblende. Small, nearly idioblastic, grains of sphene are sprinkled throughout.

Alteration of the plagioclase to sericite is minimal. Overall, the sample is fairly fresh.

SAMPLE 8/71-

Hand Specimen

Medium gray with greenish cast on fresh surface, weathering to darker gray.. Predominately fine grained quartz, feldspar, and calc-silicate minerals cut by thin but continuous lenses and bands of quartz and plagioclase. These bands and the orientation of the biotite plates produce a good gneissic foliation.

Thin-section

-Composition:

Quartz, plagioclase, diopside, biotite, hornblende, sericite, and sphene. Traces of zircon, apatite, rutile, pyrite, graphite, and iron oxide dust and clays.

-Summary description

Crystalloblastic texture with foliation of biotite. Mineralogically similar to 8/39, but this sample has much more consistent grain size (average of 0.5 mm) and show less sign of mechanical deformation. However, rotation of some of the diopside grains is evidenced by misorientation of included biotite to the foliation, and by pockets of granulation.

Sphene is less common and alteration rims of hornblende around diopside are much more frequent.

Sericitic alteration of plagioclase is moderate, and some clay and iron oxide dust is present.

SAMPLE 8/92-

Hand Specimen

Overall medium gray on fresh surface, weathering to dark brownish gray. Tightly folded, fine grained material of quartz, feldspars and calc-silicate minerals with irregular lenses and pods of medium grained quartz and plagioclase. Pyrite recognizable in the hand specimen.

Thin-section

-Composition:

Quartz, plagioclase, hornblende, actinolite, biotite, clinozoisite, diopside, sphene, pyrite, and sericite. Traces of muscovite, epidote, chlorite, zircon, apatite, rutile, hematite, graphite, and iron oxide dust and clay.

-Summary description

Crystalloblastic texture with foliation produced by biotite and lineation by the amphiboles. Highly variable grain size, but 0.7 mm is a close average. This sample is again similar to 8/71 and 8/12 mineralogically, but the replacement of diopside by amphiboles (chiefly actinolite) is much more pronounced, resulting in a symplictic structure. The appearance here of skeletal clinozoisite is quite noticeable. Again, some evidence of cataclastic deformation is present.

The plagioclase is cracked and these filled with sericite. Overall, more highly weathered than the previous two.

SAMPLE 8/104-

Hand Specimen

Light medium gray with slight yellowish cast on fresh surface, weathering to medium gray. Clastic texture of medium grain size quartz and feldspar with thin dark bands of biotite. The biotite is undulose around the porphyroclasts.

Thin-section

-Composition:

Microcline, quartz, chlorite, plagioclase, sericite, muscovite, biotite, and iron oxide dust and clay minerals. Traces of epidote, zircon, apatite, rutile, and pyrite.

-Summary description

Cataclastic texture with foliation produced by biotite, chlorite and muscovite. Porphyroclasts of microcline, quartz and plagioclase (up to 4mm) surrounded by fine grained material showing growth mosaic structure. Veinlets of quartz up to 1 mm cut the sample parallel to the foliation.

Muscovite is skeletal (occasionally symplictic) in plagioclase. The chlorite is complexely intergrown with opaques and also interleaved with biotite.

Alteration of this sample is intense. Nearly all of the plagioclase is riddled with sericite and muscovite. Iron oxide dust and clay minerals are present.

SAMPLE 8/141-

Hand Specimen

Medium greenish gray on fresh surface, weathers to deep reddish brown. Foliation produced by thin irregular lenses of quartzo-feldspathic composition cutting a granoblastic groundmass of quartz, feldspar and amphibole. Flecks of Pyrite noticeable in hand specimen.

Thin-section

-Composition

Quartz, plagioclase, chlorite, sericite, hornblende, pyrite, iron oxide dust and clays, grunerite, and sphene. Traces of clinozoisite, zinc, apatite, magnitite, and graphite.

-Summary description

Crystalloblastic texture in general with an average grain size of 0.5 mm. This pattern is cut by brightly irregular quartzose veinlets up to 2 mm thick which show a sutured pattern. Foliation is produced by chlorite and biotite with a crude lineation in the same plane by the amphiboles hornblende and grunerite. Irregular grains of pyrite are common throughout, as are more regular grains of sphene.

The specimen is highly altered with every grain of plagioclase containing sericite or symplictic muscovite.

SAMPLE 8/143-

Hand Specimen

Medium light gray on a fresh surface, weathering to yellow-brown. Fine grained, thinly laminated gneiss with larger grained layers of quartzo-feldspathic composition.

Thin-section

-Composition:

Quartz, plagioclase, biotite, hornblende, sericite, actinolite, chlorite, and graphite. Traces of muscovite, zircon, apatite, rutile, monazite, pyrite, hematite, and iron oxide stain and clays.

-Summary description

Crystalloblastic texture with elongated porphyroblasts of hornblende up to 1 mm in length in a groundmass of quartz, plagioclase and biotite averaging 0.5 mm. Porphyroblasts are somewhat poikiloblastic with inclusions of quartz and plagioclase. Foliation is produced by biotite, and crude lineation is produced by the hornblende. Thin, irregular trains of quartz with sutured boundaries are common.

The biotite is interleaved with graphite and other opaques and, on occasion, chlorite. The plagioclase contains a moderately high amount of sericite.

SAMPLE 8/150-

Hand Specimen

Medium light gray on fresh surface, weathers to yellowish brown. Predominately fine grained with foliation produced by biotite and muscovite. Layering produced by thin quartzo-feldspathic lenses.

Thin-section

-Composition:

Quartz, plagioclase, biotite, sericite, chlorite, muscovite, graphite, grunerite, actinolite, clinozoisite, apatite, and iron oxide stain and clays. Traces of hornblende, zircon, hematite, and magnetite.

-Summary description

Overall crystalloblastic texture with occasional fine grained granulation. Foliation produced by biotite and chlorite, and a compositional layering . There is a predominately equal distribution of quartz and feldspar throughout, but the platy minerals (biotite and chlorite) have been crudely seperated into bands rich in one or the other. The average grain size is 0.4 mm, but larger porphyroclasts and smaller granulated material is present.

The chlorite is highly interleaved with opaque dust and graphite. The plagioclase is highly altered to sericite and clay minerals.

ACKNOWLEDGMENTS

I would like to express my thanks to Dr. George E. Moore, Jr. for making these samples available for study and also for his interest in and assistance with this thesis.

BIBLIOGRAPHY

Dixon, H.R., and Pessl, Fred, Jr., 1966, Geologic map of the Hampton quadrangle, Windham and Tolland Counties, Conn. : U.S. Geol. Survey Geol. Quad. Map GQ-468.

Heinrich, E. Wm., 1956, Microscopic Petrography: McGraw - Hill, New York, 296p.

Kerr, Paul F., 1959, Optical Mineralogy: McGraw & Hill, New York, 442p.

Lundgren, L.W., Jr., 1966, Muscovite reactions and partial melting in southeastern Connecticut: Jour. Petrology, v. 7, p. 421-453.

Spock, L.E., 1953, Guide to the Study of Rocks: Harper and Brothers, Publishers, New York, 256p.

Spry, Alan, 1969, Metamorphic Textures: Pergamon Press, New York, 350p.

Turner, Francis J., 1968, Metamorphic Petrology Mineralogical and Field Aspects: McGraw - Hill, New York, 403p.

Winkler, H.G.F., 1967, Petrogenesis of Metamorphic Rocks: Springer - Verlag New York Inc., New York, p. 94-115.

Turner, F.J. and Verhoogen, J., 1960, Igneous and Metamorphic Petrology: New York, Toronto, London.